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THIS ISSUE

Relation of Piston Rings to Effective Cylinder Lubrication

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Relation of Piston Rings to Effective Cylinder Lubrication

ATTAINMENT of successful engine or compressor operation is contingent upon a number of factors, which involve both design and operation. Among the most important are piston rings and lubrication. They require more than passing consideration, by reason of their dependence upon each other, for neither could function independently.

In full realization of this fact, the petroleum industry has studied the various requirements of engine and compressor cylinder operation, particularly with respect to the range of temperatures and pressures which lubricating oils must withstand. Foundry and machine shop authorities in turn, have studied the manufacture of piston rings from a metallographic or iron structure viewpoint, as well as mechanical design; all to the development of a better understanding of each other's problems.

Mention of temperature ranges requires more detailed consideration of the prevailing limits as they exist today in modern engine or compressor operation. It is these limits, in fact, which have been so influential in bringing about study of relative hardness in piston ring and liner construction.

The lowest range of cylinder temperatures are found in refrigerating compressor service. The piston type of pump, air compressor, steam engine, gas engine and Diesel will show rising temperatures normally in the order named. Some variation will, of course, occur, dependent upon individual operating conditions. There will also be instances of overlapping. For this reason study of the average temperature range in any particular installation must be made by the lubricating engineer in deciding upon the oil to use, or the piston ring authority in recommending any specific type or hardness of ring.

The thoughts of the former must be particularly directed towards viscosity or relative fluidity, for the extent to which effective piston sealing can be maintained under operating temperatures will largely depend upon this property. Obviously too thin an oil may permit blow-by to occur. Conversely, too heavy an oil may cause drag, overheating and abnormal power consumption.

It is not enough for the oil viscosity to be right, commensurate with cylinder conditions. To insure against blow-by or abnormal wear, certain authorities feel that ring material must show:

1. A dense, uniform graphite distribution.
2. A well defined pearlitic matrix, bordering on the sorbitic stage to insure adequate resistance to wear, and
3. Freedom from segregated constituents.

FUNCTION OF PISTON RINGS

Piston rings perform a number of functions in engine, pump or compressor operation. In service when heat is developed or applied, as in

the Diesel or other types of internal combustion engines, the steam engine or some air compressors, piston rings serve to maintain compression, control lubrication and conduct heat away from the combustion, power or working chamber to the cylinder walls as well as the

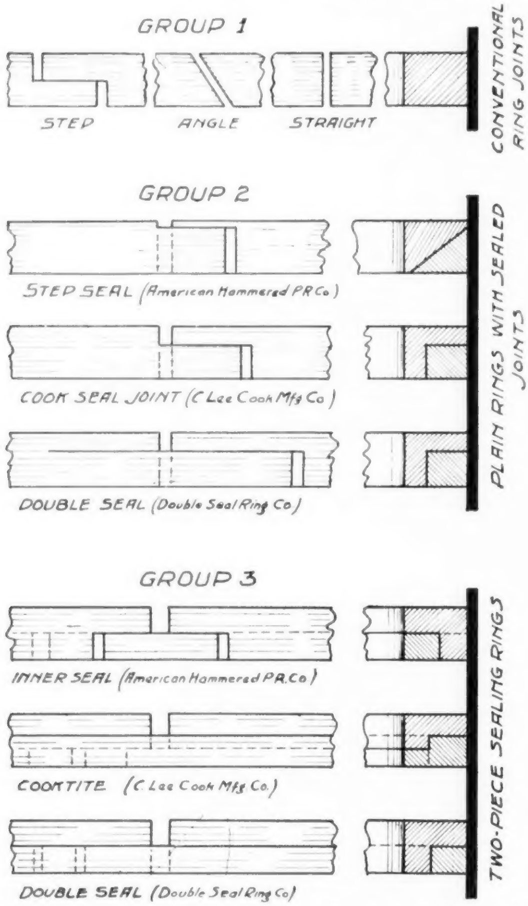


Fig. 1—Showing constructional details in section and side view for piston rings with the conventional type of joints; also, various types of designs of plain rings, with sealed joints, and two piece sealing rings. For worn cylinders, the trend seems to be toward the use of two piece sealing rings.

piston, whence the cooling systems can perform their functions. In pump and refrigerating compressor service the duty is not as severe, for heat conductivity is not an important factor. When a set of piston rings is capable of performing these functions effectively, by reason of judicious design, proper installation, and intelligent application of cylinder lubricating oil, the ultimate objective—prevention of wear by preservation of an adequate lubricating film under all conditions of operation—will more nearly be accomplished.

Relation of Compression Loss to Blow-by

Maintenance of compression is of vital importance because when loss of compression develops blow-by will be bound to occur, allowing the hot gases from the combustion or power chamber to pass the rings. This destroys the protecting oil film and permits metal to metal contact of rings and cylinder, resulting in excessive friction, heat and wear. The intimate relationship of blow-by to piston rings must therefore be thoroughly realized.

Blow-by is also influenced by piston speed, according to one well known manufacturer,* who states that—"engines with a piston speed of approximately 1000 feet per minute are not subject to appreciable leakage or blow-by through the joint. On the higher speed engines blow-by usually occurs on the outside diameter of the ring adjacent to the joint. This condition is greatly exaggerated in high speed automotive engines and can be corrected by giving additional support to the weak section of the ring near the joint. This is generally accomplished by manufacturing the rings with plus circularity. In other words, when a ring is measured at various points around its circumference while held in a flexible band of cylinder size, it is said to have plus circularity if the axis through the joint is greater than the axis 90 degrees from the joint. Rings with plus circularity will have greater pressure at the joints than rings with zero circularity or minus circularity. This additional strength at the weakest section of the rings is essential in all high speed engines, and, the greater the piston speed, the greater the plus circularity required. On the other hand, regardless of the amount of plus circularity that a ring has when placed in a flexible band, it must, of course, conform perfectly to a true cylinder when confined in the cylinder."

"In engines with a piston speed of less than 1000 feet per minute, leakage through the joint must be considered. This leakage may destroy the oil film at the start, causing wear at the point of passage. Several types of single-piece piston rings with special joints as well as numerous designs of multiple-piece rings are manufactured which develop excellent joint seals. Seal rings, while of questionable value in new engines, are frequently essential in badly worn cylinders. For example, consider a 20 inch ring in a cylinder having a taper of 0.100 inch. If this ring has the normal gap clearance of 0.100 inch at the smallest part of the cylinder, it will have a gap clearance of 0.100 inch plus 3.14 times 0.100 inch or a total of 0.414 inch at the largest part of the cylinder. Under such conditions, which are not unusual, a seal ring is obviously desirable."

"In addition to the requirements that it must be perfectly round in the cylinder with the proper radial pressure at all points, a ring also

* The American Hammered Piston Ring Company

must be perfectly flat so that a seal is assured against the lands of the groove. By suitably providing for these factors in the manufacture of the rings, blow-by can be reduced to the minimum."

Control of Lubrication—Ring Pressure

Control of cylinder lubrication by uniform distribution of oil over the cylinder walls must be maintained by the piston rings. This function is intimately related to prevention of oil pumping and blow-by due to the detrimental effect which the latter especially will have upon the oil film on the cylinder walls on the working stroke. The tension in the compression or power rings must, therefore, be sufficient to press the oil film tightly and evenly against the cylinder wall. It must, of course, be uniform over the entire contact surface of the rings, for any uneveness may lead to so-called "high spots" in the film and develop oil pumping or passage of an excesss of lubricating oil past the rings into the compression or top side of the engine or compressor.†

The same authorities* state that:—

"A light tension ring rides up on the oil, leaving a very light tension film. On the working stroke, a weak film of oil is easily blown out of the space between the ring and cylinder so that the ring rubs against the cylinder, unprotected by oil, thus starting wear. On the other hand, an oil film which is pressed firmly by a piston ring will have sufficient tension in itself to resist blow-by, thus forming a perfect seal and preventing wear."

"The oil control ring must have sufficient unit pressure in order to remove excessive oil from the cylinder wall. This pressure can be twice that of a compression ring without danger, as the oil ring is away from gas pressure and well lubricated. This high unit pressure can be secured by cutting down the cylinder contacting surface so as to reduce the bearing area, as on bevelled and grooved rings."

"A slotted ring also has a greatly reduced bearing area and correspondingly increased unit pressure. The operation of the slotted ring may be described as follows: As the advancing edge of the ring passes over the film of oil on the cylinder, it exerts a heavy pressure which is suddenly relieved over the area of the slots. The oil then rushes into the slots in the same way that water rushes in behind a moving ship. The following edge of the ring keeps the oil in the slots and guides it towards the drain holes in the back of the piston groove."

"The unit pressure of rings can be increased by the use of expanders. When these are provided with oil vents they may be used effectively in conjunction with slotted oil rings."

"When slotted rings are used, as is customary on four-cycle engines, it is necessary to have

Courtesy of The American Hammered Piston Ring Co.

Fig. 2—Showing various types of rings, manufactured by the above company. At the top is the Cronin inner seal ring, followed by a type of oil control ring. Below that is shown a bevelled and grooved ring. In the installation of this ring oil relief passages in the piston below the ring, but connecting with the groove in the ring, may be drilled in order to drain excess oil back into the crankcase. The expander, which is also shown, is installed in back of certain types of rings, to increase tension.

drain holes drilled in the back of the piston grooves. Ample area of drainage must be provided both in the slots in the rings and in the holes in the piston because insufficient area will retard the quick passage of excess oil and cause the holes and slots to clog up. When the

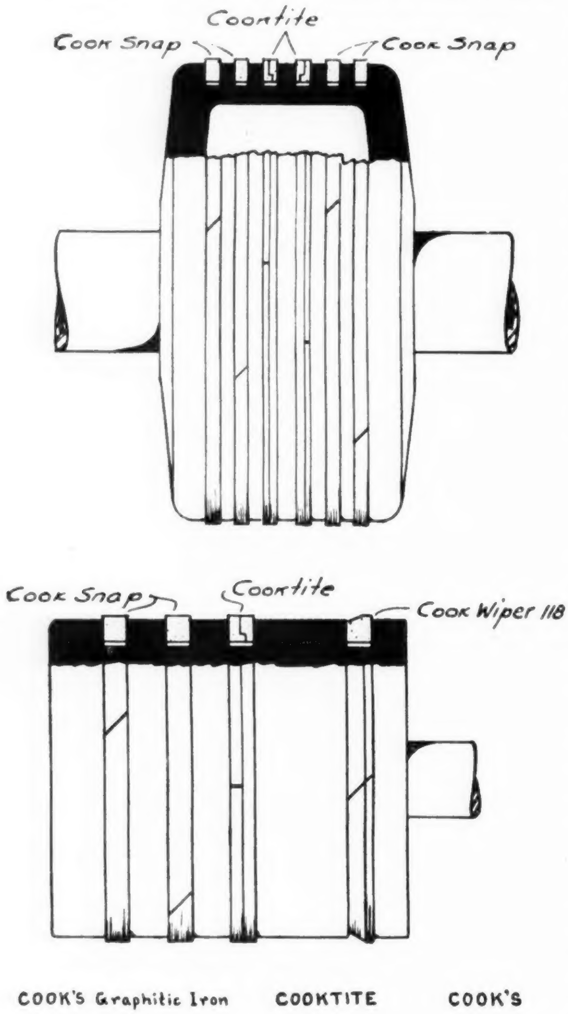
† There is of course difference of opinion as to just what ring tension should be, also the relative advantages of wide versus narrow rings. Hence our quotation from manufacturers.

pistons are not drilled or when all of the drilling is below the ring grooves, bevelled rings are used as oil scrapers."

Depth of Piston Ring Grooves

Inasmuch as one of the principal functions of a piston ring is to transfer heat, the radial or wall thickness of the rings and corresponding depth of the grooves in the piston is of distinct importance. In the opinion of certain authorities this has been too frequently over-looked, with the result that many pistons in the past have been designed with grooves entirely too shallow. In this regard, trade standards recommend a radial depth of 0.040 inches per inch of diameter. This is about the maximum that can safely be sprung over a solid piston.

In addition to insufficient heat transfer, other detriments which may result from too shallow ring grooves will include sticking of rings, accumulation of carbon, blow-by, abnormal groove wear and sometimes distortion of the ring itself. This latter may occur where attempt is made to use a deeper ring than the grooves are designed for. In regard to blow-by, it is also of interest to note that some authorities feel that depth of ring grooves in pistons is directly related to amount of blow-by, the one becoming therefore a measure of the other.



Courtesy of C. Lee Cook Manufacturing Co. Inc.

Fig. 3—Showing a method of installing Cooktite piston rings in four-cycle and two-cycle gas engines. The top view shows installation of rings on a double acting four-cycle engine; center view shows a similar installation for a single acting four-cycle engine; bottom view pertains to a two-cycle engine.

EFFECT OF FUEL QUALITY AND COMBUSTION

In Diesel engine service study of performance of piston rings and cylinder liner wear should commence with the fuel, particularly in view of the fact that considerable wear will result if this latter contains any appreciable amount of abrasive, foreign matter. Wear may also be affected by improper combustion.

In addition to wear, a fuel of comparatively high foreign matter content may cause the piston rings to stick and the valves to function imperfectly, due to accumulation of such matter around the valve stems.

For this reason careful study should be given to the fuel analysis and installation of suitable equipment for purification prior to usage. It is practicable to remove virtually all suspended solid or non-combustible matter from the average Diesel fuel with the centrifugal purifier. Unfortunately sulphates developed as products of combustion in high sulfur-content oils remain to sometimes become detrimental in contributing to liner wear, especially where they may have united with iron to increase their abrasive nature. Combined with carbonaceous residue from either the fuel or lubricating oil, such sulphates of iron are one of the chief causes of stuck rings. The sulfur content should therefore never be overlooked, especially since it introduces the added possibility of development of corrosion due to acid formations in the presence of moisture particularly on standby.

Incomplete Combustion

Whatever the cause of improper combustion, the result will be that all of the fuel supplied to

the combustion chamber is not completely burned. Where this occurs the unburned portions of the atomized fuel will to some extent be caught by the thin oil coating on the cylinder walls, or else tend to creep past the piston rings, eventually to reach the base, wherever the design makes this possible.

In the first case, the quality of the cylinder lubricant may suffer due to change in viscosity or due to the content of solid matter. In the second case, the quality of the lubricant in the base will be lowered, thus leading to excessive bearing wear.

Fuel Quality

Ash content in the fuel is another cause of excessive wear. Ash is the non-combustible mineral matter dissolved or suspended in the fuel. Unless effective oil filters are used, a considerable portion of this mineral matter will exist in the form of an extremely fine powder after combustion, capable of being swept out and carried along by the exhaust gases. Some of it will be caught in the lubricating oil film, thus impairing lubrication and increasing wear. But however serious wear may be, due to excessive ash content, it certainly cannot be held responsible for the fact that cylinder liners do not wear uniformly, but instead show maximum wear very near the top of the stroke, ultimately becoming barrel-shaped.

It is significant that the zone of maximum wear is indicated where maximum pressure and temperature exist in the cylinder and where the piston speed is lowest. The exact reason for this is not quite understood, but it seems reasonable to expect a metal which is intermittently heated and pressure stressed to wear more than one which is stressed to a much less degree.

Certain authorities feel that for a given cylinder size, wear and revolutions per minute may be related. In contrast, in the estimation of others, increased piston speed would tend to a more even distribution of wear.

RELATION OF LUBRICATION SEAL TO CYLINDER WEAR

Piston rings must bear evenly over their entire surface of contact with the cylinder walls if effective lubrication and seal are to be maintained. To insure even bearing, the rings must fit evenly in their grooves, and yet be capable of free movement, or floating. For this reason it is highly essential that the grooves be accurately machined and absolutely parallel. Proper fitting will also insure even bearing on the sides of the grooves, which will afford a further advantage in preventing accumulations of carbon and leakage of steam, air or gases of combustion back of the rings, to cause loss of compression. Maintenance of compression should, therefore, be indication of not only suitable ring installation, but also effective lubrication. Study of Diesel engine operations under test conditions has borne out the truth of this assumption.

In connection with this matter of ring fit and installation, the type of ring should always be studied, for with certain designs it is possible to install them upside-down, a procedure which would lead to abnormal oil consumption, impairment of the seal and loss of compression.

Freedom of motion is also very essential. Obviously it cannot be assured even with the best of lubrication, if the rings bind mechanically. The utmost care should therefore be given to the clearance space between the ends of the rings. Too slight clearances may lead to excessive liner wear, for obviously if a ring cannot expand freely without actual contact of its butt ends, it will drag over the liner, even breaking in certain cases, due to the vibrations developed, particularly on the explosion or expansion strokes.

When fully compressed, certain authorities

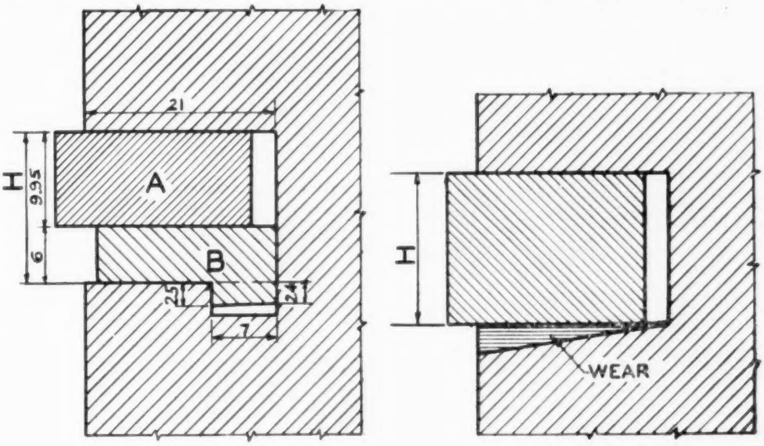
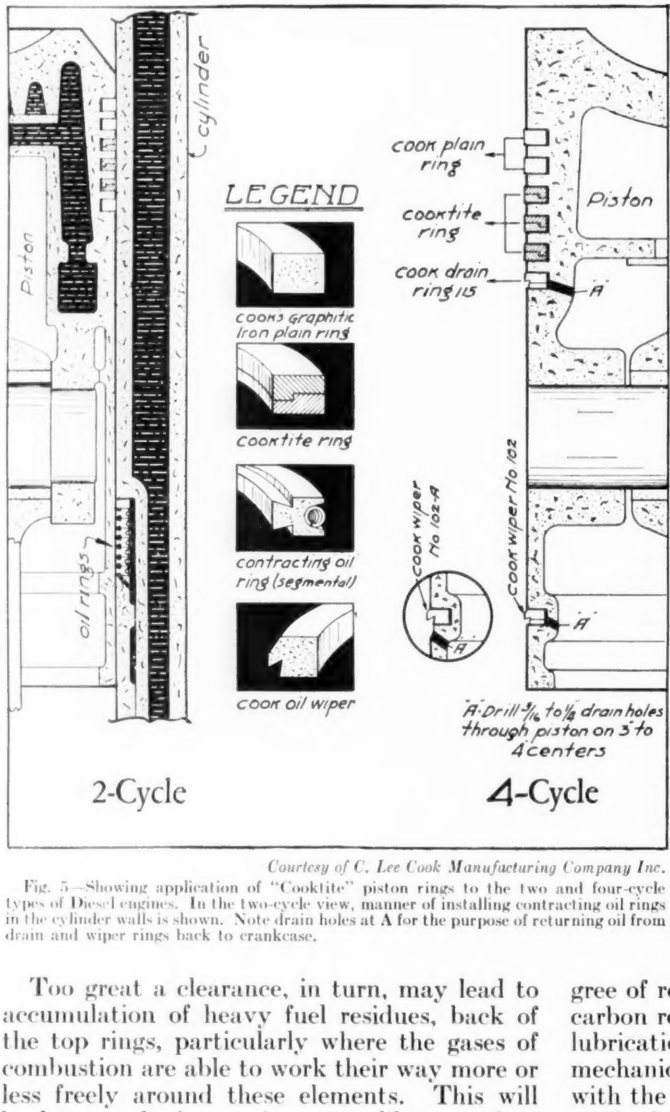


FIG. X FIG. Y

Courtesy of Belships Company, Ltd. and Davy Robertson Engineering Co.

Fig. 4—Showing a method of piston ring installation whereby wear of the lower edge of the piston ring groove can be markedly reduced. Principle involves use of a wear ring "B," which does not extend to the outside circumference of the piston. This ring serves to maintain a true and parallel surface for service ring "A", insuring also that intended height "H" of the piston ring groove remains unaltered. With the conventional method of ring installation as shown in Fig: Y, wear will tend to develop on the underside as shown, leading to increase in the height "H" of the groove. This is claimed to influence both lubricating oil consumption and breakage of rings. Dimensions shown in Fig. X are in millimeters. The particular installation involves a cylinder diameter of 600 m.m., six rings being used.

feel that in Diesel service ring clearance should range from three to five thousandths of an inch per inch of cylinder bore, the most space being necessary at the top ring to compensate for material expansion under the higher temperatures which will prevail.



Courtesy of C. Lee Cook Manufacturing Company Inc.

Fig. 5—Showing application of "Cooktite" piston rings to the two and four-cycle types of Diesel engines. In the two-cycle view, manner of installing contracting oil rings in the cylinder walls is shown. Note drain holes at A for the purpose of returning oil from drain and wiper rings back to crankcase.

Too great a clearance, in turn, may lead to accumulation of heavy fuel residues, back of the top rings, particularly where the gases of combustion are able to work their way more or less freely around these elements. This will lead to stuck rings quite as readily as carbon accumulations from excessive use of unsuitable lubricating oil.

The Cause of Blow-by

It is the opinion of many that the chief cause of blow-by is traceable to excessive lubrication and carbon formation around the rings, particularly in worn cylinders, the lubricant seal being subsequently destroyed by leakage of gases under pressure past the rings. Such formations will reduce free motion of the rings and ultimately cause them to stick, particularly where higher temperatures of the expanding or compressed gas are involved. In this regard it is well to mention that in the air compressor, the working temperatures are often lowest, increasing where steam is involved, and becoming highest in the Diesel, or ignition type of internal combustion engine. These temperatures would range from an average of perhaps 250 degrees Fahr. for air, to 500 degrees Fahr. for normal pressure superheated steam. In the Diesel engine, however, they would range up to the neighborhood of 2800 degrees Fahr. Obviously if gases of even 200 to 300 degrees Fahr., temperature were to blow past the piston rings relatively unretarded, they would very soon cause abnormal vaporization of the lighter or more volatile fractions contained in the lubricating oil, to result in accumulation of heavy residues which would bake around the rings. The higher the temperature of the gases the more rapidly will this take place.

It is evident that such an occurrence should not be charged to the lubricating ability of the oil, for any petroleum product will vaporize and develop heavy residual formations if subjected to sufficiently high temperatures for any length of time.

Once free motion is impaired more or less blow-by can be expected, regardless of the type of engine or compressor. As this continues, liner wear will often develop adjacent to the cylinder heads, particularly in the internal combustion type of engine. Free motion of the rings can be aided by controlled lubrication, provided the oil used is of a high degree of refinement and shows a sufficiently low carbon residue content. In practice, control of lubrication is most readily attained by use of a mechanical force-feed lubricator, in connection with the average steam engine, air compressor, or the larger type of Diesel or gas engine. In smaller trunk-piston type internal combustion engines, however, practice is to maintain cylinder lubrication by splash.

The Benefit of Low Carbon Residue

In this connection the value of low Conradson carbon residue in lubricating oils, especially in air compressor and internal combustion engine service, should never be overlooked. The beneficial results of this factor in connection with Diesel engine operation are particularly noteworthy. Actual experience has

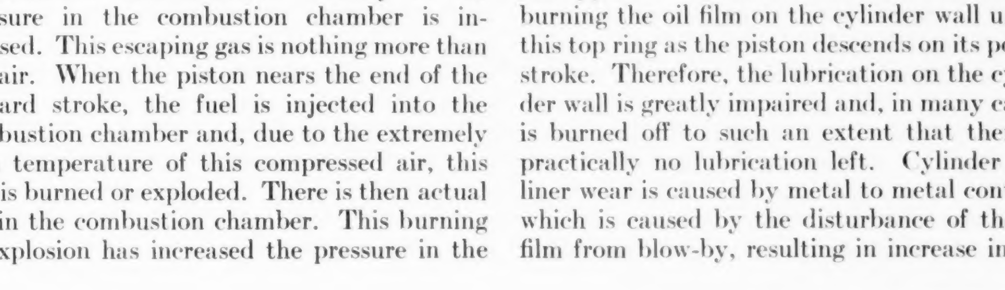
indicated that using an oil of less than 0.1 per cent carbon residue, fouling of rings will be materially reduced with resultant maintenance of compression and remarkably low oil consumption. In one particular high speed test which was run to approximate service conditions for 700 hours, no appreciable loss of compression was shown, make-up was less than 2 per cent of the total amount of oil charged, and analysis of the used oil indicated that wear was virtually negligible.

Effect of Blow-by on Lubrication and Cylinder Wear

Discussing the effect of blow-by in connection with lubrication and cylinder wear in typical Diesel engine service, one ring manufacturer** states:

"When the piston ascends on the compression stroke, the air which has been drawn into the combustion chamber is compressed to about 480 pounds and the temperature is raised to about 1000 degrees, Fahr. A part of this pressure begins to escape as the piston starts up. It continues with increased velocity as the pressure in the combustion chamber is increased. This escaping gas is nothing more than hot air. When the piston nears the end of the upward stroke, the fuel is injected into the combustion chamber and, due to the extremely high temperature of this compressed air, this fuel is burned or exploded. There is then actual fire in the combustion chamber. This burning or explosion has increased the pressure in the combustion chamber to about 700 pounds and the temperature to about 2,800 degrees, Fahr. The leakage at this point has changed from hot air to fire. Let us now consider the effect of this fire in conjunction with leaky rings."

"After an engine has been run for a few months or years, there has been a certain amount of wear on the cylinder walls. The greatest wear has taken place near the combustion chamber, or upper part of the cylinder. In fitting piston rings they must be fitted to the smallest or lower part of the cylinder. Therefore, when the rings travel to the top of the cylinder where the bore is greatest, the gap opens and, as above described, the ring has its greatest gap at the top of the cylinder at the time the pressure is greatest and the temperature is the highest in the combustion chamber. In other words, the largest gap is exposed to the actual fire in the combustion chamber, which is trying to escape through this gap. It passes through this gap at a time when the piston is at the top, when the load on the piston is the greatest and hottest, and the fire which passes this gap is almost equivalent to a welding torch. This torch-like effect passing through the gap of the top ring strikes the top of the second ring just below and spreads on the cylinder wall, traveling toward the gap of the second ring on the opposite side. This torch-like effect then, is burning the oil film on the cylinder wall under this top ring as the piston descends on its power stroke. Therefore, the lubrication on the cylinder wall is greatly impaired and, in many cases, is burned off to such an extent that there is practically no lubrication left. Cylinder and liner wear is caused by metal to metal contact, which is caused by the disturbance of the oil film from blow-by, resulting in increase in the cylinder wear, and is very expensive, both from the standpoint of lost power and repairs."



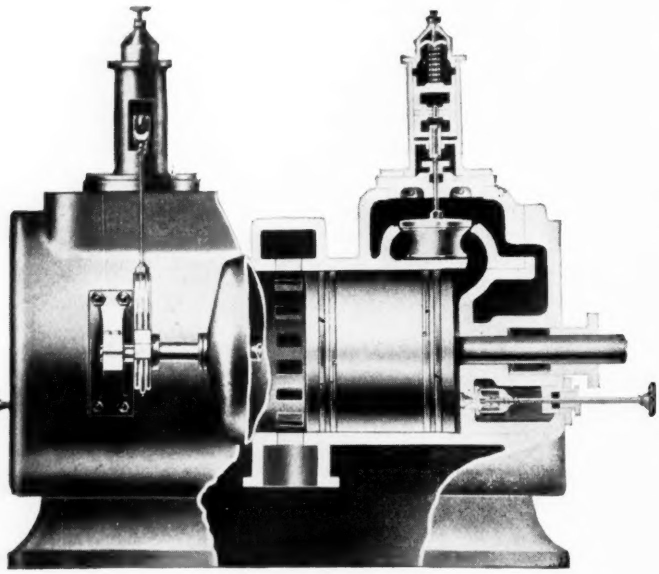
Courtesy of Double Seal Ring Company

Fig. 6—Showing various methods of piston ring application. Fig. A illustrates application of piston rings to a 4-cycle oil or gas engine inclined to use excessive lubricating oil; B shows application of rings to a 4-cycle oil or gas engine; Fig. C shows application of rings to a 2-cycle oil or gas engine, and D shows installation of rings on the piston of a single acting ammonia compressor.

While most engine builders consider the two-piece sealing ring as a repair ring for use after cylinder wear has occurred, there are some manufacturers who feel that blow-by com-

** Double Ring Seal Company.

mences soon after the engine is put into service, or as soon as the joint openings of the plain rings enlarge from the combined wear of cylinder and ring. By using sealing rings at the outset, the possibility of blow-by destroying



Courtesy of Double Seal Ring Company
Fig. 7—Cutaway view of a uniflow steam engine wherein one piece double seal rings are installed on a four ring piston in combination with two plain rings.

lubrication is eliminated and this in turn guarantees longer life of cylinder and rings. The location of sealing rings on the piston is still a matter of opinion that greatly varies. Most ring manufacturers, however, recommend the use of several plain rings ahead of the sealing rings or in the grooves nearest the top. One in particular‡ states:—"The location of two-piece sealing rings on Diesel pistons, and the number of sealing rings to be used, depends to a large extent on the amount of cylinder wear that has occurred. If cylinder enlargement at the maximum point of wear does not exceed 0.005 inch per inch diameter of cylinder, two sealing rings will suffice, placed in grooves No. 3 and No. 4, with ordinary plain rings in grooves No. 1, No. 2, No. 5 and No. 6 on a piston carrying six compression grooves. If cylinder enlargement at the maximum point of wear exceeds 0.005 inch per inch diameter of cylinder, three sealing rings should be used, in grooves No. 3, No. 4 and No. 5, with plain rings in the other grooves."

Ring Pressure

The extent to which so-called back-pressure or pressure developed by penetration of air, steam or gases of combustion back of certain types of piston rings should be regarded as a contributing cause of abnormal liner wear, is open to discussion. Obviously within a restricted chamber exposed to pressure such as is formed by the cylinder head and that portion of the cylinder wherein expansion or compression takes place, there will be a tendency toward equalization of pressure. In other words while the pressure prevailing above and around the piston will in many cases also find its way to the annular spaces in back of at least the uppermost piston rings, the outward force exerted in back of these rings will largely be offset by a force of equal intensity working against the exposed parts of the rings.

‡ C. Lee Cook Manufacturing Company.

Gas Pressure vs. Ring Tension

It is important to differentiate between the relative effects of ring tension and gas pressure upon liner wear. The former is essential in the interest of reducing blow-by and maintaining a suitable seal; the latter is inherent to operation. Average practice is to use rings which will exert a pressure of from 6 to 10 pounds per square inch of contact surface. Normally this will not be sufficient to cause extensive wear, unless lubrication is seriously impaired. It is sufficient, however, to maintain an adequate seal in company with effective lubrication, to materially prevent blow-by and the wear-producing effects of gas pressure past the rings, especially when these latter are capable of flexible action in comparatively clean, parallel piston grooves.

Wear as it results from gas pressure is a function of velocity, being actually a form of erosion. As a result, the higher the pressure to which the piston may be exposed upon its expansion or compression strokes, according to the type of engine or compressor, the greater the potential velocity of the gas at the point of leakage, consequently the greater the resultant wear. On the other hand, it is minimized in the high speed Diesel, especially, by improved methods of cooling and the use of positive means of lubrication.

Use of Alloy Cast Iron Liners

Recent studies in connection with alloy cast iron liners has led to some particularly interesting conclusions in regard to the effect of such alloys upon elasticity and resistance to temperature stresses. As a potential preventative of cracked liners, the use of such alloys is worthy of careful consideration.

According to certain foreign authorities, analysis of liner cracks over a period of several

years has indicated marked similarity in occurrence. These have been observed to start at the upper edge of the inside bore of the liner, extending downward and outward until they reached the outside, when water leakage occurred. It is reasonable to presume that such cracks are caused by temperature stresses, aided by lack of adequate cooling in liners of conventional design.

To overcome this, alterations in machining of the tops of liners have been studied, as shown in Figure 9. This involved removal of part of the material in the upper edge of a liner, and rounding off this edge as indicated. Research of certain European authorities has indicated such construction to exert a marked effect in equalizing and reducing temperatures and stresses at liner tops, where otherwise extremely high temperatures would be concentrated.

The use of vanadium, chromium and nickel alloy constituents where thorough and even distribution throughout the casting is brought about, has been found to increase strength and resistance to wear with encouraging maintenance of compression and economy of lubricating oil.

Hardness of Materials

Relative to the hardness of metal required for piston rings for various types of engines and compressors, it is interesting to note that the trend is apparently to use softer grades of iron wherever it is difficult to maintain adequate lubrication.

Hardness of piston ring metal is controlled by the size and manner of handling in the process of manufacture. In softer irons a larger percentage of the total carbon is in the primary graphite state. In the harder types of rings, on the other hand, there is less primary graphite and more combined carbon.

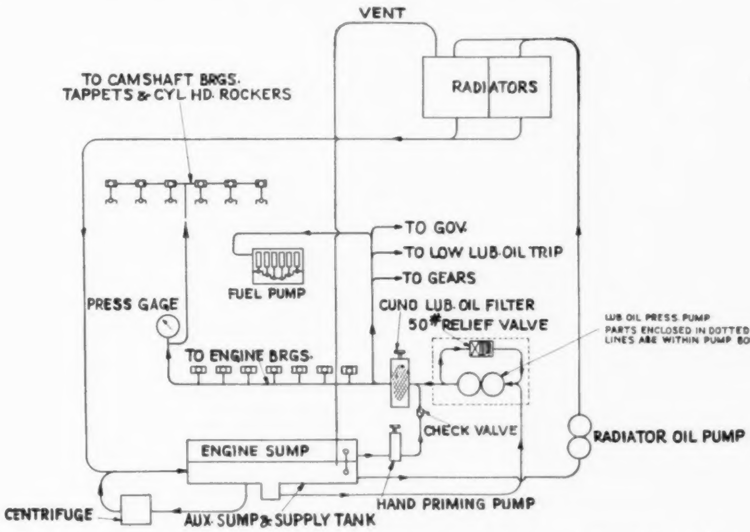
Tests have indicated that excellent results will be obtained when both rings and liners range above 160 in Brinnell hardness, particularly for internal combustion engine service, although certain authorities feel that in the smaller sizes the allowable hardness may range considerably above this figure. As a general rule the thinner the rings the harder they will be, due to quicker cooling in the process of manufacturing. For classes of service wherein operating temperatures will not run as high as in the internal combustion engine some ring manufacturers build a type of ring somewhat softer than 160 Brinnell.

Relative to cylinder liners, many authorities believe that the hardness should exceed that of piston rings to a certain extent. Where alloys such as nickel, chromium or vanadium are used in the manufacture of liners the resultant initial hardness will be materially increased, although it may change somewhat after continued service.

EXPANSION AND LOCATION

In Diesel engine service the prevailing temperatures to which the pistons are exposed as they approach the combustion chamber requires careful consideration of expansion at the top of the former, and the location of the rings nearest the top. Expansion is taken care of by slightly tapering the pistons at the top. The extent of the taper, however, depends upon their metallic structure with respect to that of the cylinder liners. Top rings must also be designed with respect to probable expansion under heat. Normally this is taken care of by providing greater side clearance and clearance between the ends of the rings.

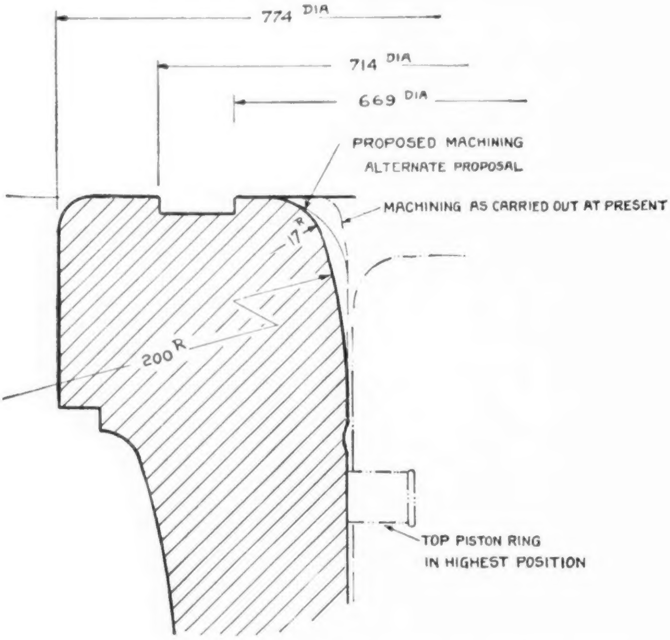
The lubricating film at the top of the cylinder walls is, of course, exposed to the highest temperatures, but it is only momentarily, for as the working stroke occurs temperatures drop rapidly. A certain amount of this film is burned, however, at each stroke. The extent to which carbon residues remain may readily



Courtesy of Westinghouse Electric and Manufacturing Co.

Fig. 8—Oiling diagram for the Westinghouse Diesel engine, showing piping arrangement and relative location of oil filter, pressure pumps and oil supply.

affect the operation of the piston rings. Should they bind or not be capable of free expansion, the ability to free themselves of any carbon deposits will be reduced. Under such conditions, according to the nature of refinement of



Courtesy of Belships Company, Ltd., and Sulzer Brothers

Fig. 9—Showing suggestion for rounding off top of a Diesel cylinder liner with a view to bringing about more even temperature distribution throughout the liner material. Dimensions are in millimeters.

the lubricating oil, and the grade of fuel, such deposits may become so increased as to cause the rings to stick and become entirely inoperative. When this occurs blow-by will be encouraged for not only will the seal be impaired, but wear will also be promoted.

As to the effect of piston and piston ring design on wear, it is to be pointed out that current practice places the first ring quite some distance below the top of the piston. The reason for doing this is to give the gases that may pass the ring a chance to cool off, thus decreasing the temperature at the most likely point of maximum wear and reducing piston ring duty.

The vertical clearance allowed for the rings also seems to be a contributing factor. Too small clearance results in undesirable restraining of the rings from their natural motion. Too small end clearances may also cause the rings to expand longitudinally on heating, and frequently to buckle. Excessive clearance on the other hand, is thought by some to permit the full gas pressure to get behind the rings and thus increase wear.

But if some wear of the cylinders is due to the eroding action of the hot gases, it is reduced by the expedient of placing the first ring at quite some distance from the top of the piston.

Authorities have suggested, with respect to the four cycle engine, that if this first ring is located at a distance from the piston head equal to approximately one quarter of the piston diameter, it will enable the lubricating film to function most effectively in protecting the contact surfaces of both the ring and cylinder liner.

In the two cycle engine the first ring must never pass the exhaust port prematurely on the downward stroke, otherwise loss of pressure may result before the stroke is completed. In such engines careful study of the length of the stroke with respect to the location of this port is essential, prior to deciding on the location of the first ring. Frequently this location must be closer to the top of the piston than in the four cycle engine. For this reason a low carbon forming cylinder oil is very necessary for continued effective lubrication of such engines, especially in view of the added fact that in such engines the cylinder temperatures may also be considerably higher.

By locating the first ring a sufficient distance below the top of the piston, the possibility of sticking, due to carbon accumulation is materially reduced, particularly where the rings are accurately fitted in their respective grooves, and are able to expand freely. There is a further advantage in that when the first ring is properly located with respect to the piston head it is more nearly exposed to the cooling effects of the piston coolant and capable of more ready dissipation of heat through the thinner layer of metal at the base of its groove.

LUBRICATING OIL CONSUMPTION

Records of certain marine installations over a period of several years have indicated some interesting data in regard to the effect of constructional and maintenance conditions upon lubricating oil consumption. Among the factors which have been particularly studied are:

The condition of oil scraper rings.

The packing of crankcase covers.

Viscosity of oil in circulation.

Viscosity of oil used for make-up.

Means for collecting cylinder and crankcase oil from scraper rings for return to the circulating system.

Prevention of oil loss through vaporiza-

tion or crankcase breathing via fittings which can be made oil-tight.

Manner of installation of piston rings.

Frequent or continuous purification of crank-case oil to reduce loss of free oil which may be carried off with sludge.

Adjustment of outboard bearings.

Mechanical prevention of oil losses which might often be regarded as due to excessive consumption or use of an oil unsuited to engine temperatures, should be given most careful attention. Consideration of this factor in connection with a discussion of piston rings is essential, for in event of apparently excessibe oil consumption the rings might very easily ve regarded as a contributing cause. One of the most important details in studying mechanical prevention of oil loss is to check the engine for tightness. Packing of crank-case covers or plates has been found to be especially helpful in this connection. They should, therefore, be carefully replaced after each inspection of the engine, the bolts being tightened uniformly to insure even bearing of the contact surfaces upon the gaskets or packing.

Installation of rings is another item which is of utmost importance. As a general rule there will be a certain amount of increase in lubricating oil consumption after renewal of piston rings, inasmuch as new rings will sometimes leak and require a certain amount of time to attain a running fit in the piston grooves. Where oil control rings of the sharp edge type are used it is highly essential to guard against installing upside down. Otherwise the ring may develop a pumping instead of a scraping action. This would, of course, result in excess lubricating oil consumption. Actual practice has indicated that in extreme cases oil consumption will be doubled if rings are not properly installed.

Where rings are properly installed tests have indicated that the consumption of cylinder oil in the two cycle engine, for example, may range from one-half to three quarters of a gram per B.H.P. hour. These figures have been indicated as a fair range, based upon study of more than twenty representative marine installations of one of the most prominent foreign two-cycle engine builders.

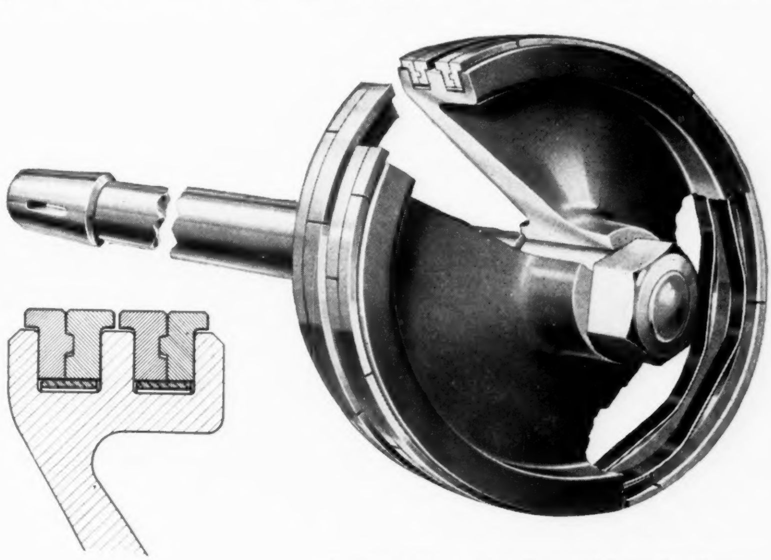
Further study of similar data, gathered most recently in connection with the use of cast iron liners carrying a small percentage of chromium and nickel, indicates that marked decrease in liner wear is being attained coincident with a gradual reduction in cylinder lubricant consumption. Inspection of liner surfaces at periodic intervals has indicated such excellent polish and condition as to justify the conclusion that the use of such alloys holds great promise as an adjunct to more effective cylinder lubrication and better performance of piston rings, especially where controlled lubrication is practicable.

AIR FILTRATION

The value of clean air as an adjunct to protection of internal combustion engine and air compressor lubrication has become fully appreciated by machinery builders, operating executives and plant engineers in the realization that air comes into the most intimate contact with the working elements of such equipment, in the performance of its intended function.

It is, of course, impossible to eliminate dirty air conditions entirely; screening of windows and doors will prevent larger particles of dust from entering, but finer dust will get by, to be an ever prevalent detriment to lubrication, unless steps are taken to remove it from the air which is to pass through the equipment, or come in contact with its wearing elements.

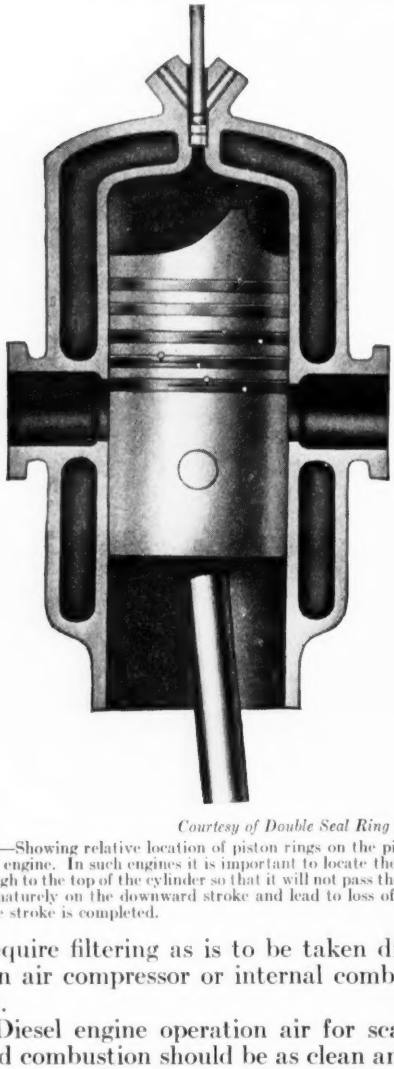
Such air, therefore, should be filtered where-ever necessary, the volume so treated per hour generally depending upon the size of the filter



Courtesy of The American Hammered Piston Ring Company

Fig. 10—Showing the American sectional packing ring, designed for steam railway locomotive service. Note the cutaway section of this type of ring, also installation of steel spring expanders. The latter forces every segment of the rings into conformity with the cylinder bore.

installation and the requirements of the plant. Normally it will not be necessary to filter all the air which is circulated through any particular room or building. In general only such air



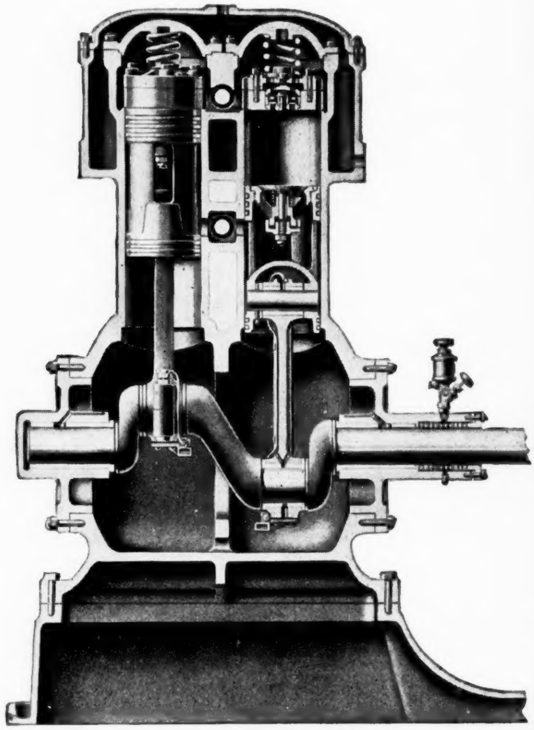
Courtesy of Double Seal Ring Company

Fig. 11—Showing relative location of piston rings on the piston of a two-cycle engine. In such engines it is important to locate the top ring near enough to the top of the cylinder so that it will not pass the exhaust port prematurely on the downward stroke and lead to loss of pressure before the stroke is completed.

will require filtering as is to be taken directly into an air compressor or internal combustion engine.

In Diesel engine operation air for scavenging and combustion should be as clean and free from abrasive foreign matter as possible. This will be most important in the full Diesel engine where air is not only mixed with the fuel prior to combustion, but is also used to bring this about. Yet, in the semi-Diesel, it is likewise of importance, for dirty air will preclude efficient operation by increasing deposits and perhaps causing scored cylinders, etc.

While all air will contain a certain amount of minute abrasive foreign matter, in certain localities and in certain industries this will be far more in evidence than in others. In marine service, for example, the Diesel engine will usually function on comparatively dust-free air, and therefore might not require any air filtration, whereas a stationary engine, operating in a stone working plant would be a decidedly



Courtesy of Frick Company, Incorporated

Fig. 12—Sectional view of an ammonia compressor showing relative location of top and bottom rings.

fit candidate for attention in this regard. The Diesel engine operator should, therefore, always determine the dust content of the air in his engine room.

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